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Neutral Surface Layer Turbulence Over Complex Terrain

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Reviewer's Abstract

Accurate turbulence estimates are important inputs to atmospheric dispersion models since they are closely related to downwind dispersion. Widely used turbulence values in the surface layer are based on a limited number of field experiments over homogeneous terrain. How valid are these turbulence values over complex terrain?

This study intends to investigate this question by analyzing a year of high-quality data taken from two multilevel towers over complex terrain. One site at Los Alamos, NM lies at the base of mountains, on a sloping, grassy field in the midst of a Ponderosa pine forest. The other site at Rocky Flats, CO also lies at the base of mountains, the Front Range. However, this site is smooth and grassy with only a few distant trees and buildings. The contrasting roughness allows a good opportunity to compare the effects of surrounding terrain on rough and smooth sites. Turbulence and wind profiles are analyzed for 8 direction sectors during near-neutral stability. Local $(z_o)_p$ and "regional" $(z_o)_{tu}$ roughness lengths were calculated from wind speed profiles and longitudinal turbulence intensities, respectively, at both sites.

Results indicate $(z_o)_p$ averages 100 cm and varies by a factor of two at Los Alamos. The $(z_o)_{tu}$ is typically 50% less than $(z_o)_p$. Rocky Flats $(z_o)_p$ varies sharply by direction, ranging from 0.2 to 15 cm. At the same time, $(z_o)_{tu}$ varies only between 1 and 9 cm. Standard deviations of wind speed (σ_u and σ_v) vary only slightly with height at both sites, in agreement with similarity theory. Ratios of σ_v/σ_u are typically 0.9 at both sites except for the 12-m level at Los Alamos, where it is 1.0. Surrounding complex terrain tends to equalize differences between the two sites: σ_u and σ_v are less at Los Alamos and greater at Rocky Flats than suggested by $(z_o)_p$. In stark contrast to horizontal turbulence, vertical turbulence shows a distinct increase with height at both sites, including a surprising 85% increase between 10 and 60 m at Rocky Flats. Vertical profiles of horizontal and vertical wind direction standard deviation ($\sigma\theta$ and $\sigma\varphi$) are plotted for 4 values of $(z_o)_{tu}$. While 10- to 12-m $\sigma\theta$ and $\sigma\varphi$ differ considerably between the sites, values from both sites nearly equal each other toward the top of the surface layer, regardless of $(z_o)_{tu}$.

This study suggests many of the widely used turbulence relationships are not valid in the neutral surface layer over complex terrain. Horizontal turbulence does vary less than 10% in the surface layer; however actual $\sigma\theta$ and $\sigma\varphi$ values are largely determined by regional terrain roughness. Vertical turbulence, σ_w, depends on local roughness near the surface and on regional roughness higher above the ground. Therefore, besides the widely known

horizontal turbulence (and dispersion) enhancement, complex terrain appears to significantly enhance vertical turbulence in the upper surface layer. Increasing height apparently allows increasingly larger vertical eddies to enhance σ_w . Therefore, measured surface layer turbulence is crucial to allow accurate dispersion model estimates for small downwind distances in complex terrain. In the absence of measured vertical profiles, the influence of regional roughness should be accounted for when estimating turbulence profiles from a single measurement level, especially when estimating σ_w . Otherwise, additional errors of a factor of 2 or more may be introduced to predicted concentrations.

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